Two Element Superdirective Array of Shorted Planar Inverted Cone Antenna

Santanu Mondal

Abstract— ***The proposed wideband shorted planar inverted cone antenna (SPICA) has been described as a two element antenna array in this paper. The two element array by this antenna with proper phase of excitation and spacing between the elements provide superdirective array characteristic. This array gives peak endfire directivity from 3.502 dBi to 10.3 dBi and radiation efficiency above 98% in the operating frequency band. Also in radiation pattern characteristic, the farfield pattern of the array is more directional than single element array. Thus the proposed SPICA is suitable for wideband antenna array applications.***

Index Terms— ***SPICA, wideband, superdirective array***

I. INTRODUCTION

Superdirective antenna arrays are a class of arrays that can be designed to achieve higher directivity than those obtained from the uniformly excited equally spaced equivalent array. Excessive array superdirectivity inflicts major problems in low radiation resistance (hence low efficiency), sensitive excitation and position tolerances, and narrow bandwidth. Superdirectivity applies in principle to both arrays of isotropic elements, and to actual antenna arrays composed of non isotropic elements such as monopoles.

The design of a superdirective array is a challenging task to the antenna researcher. Uzkov [1] has shown that the directivity of a linear array of N isotropic radiators yields a maximum value of N^2 in the endfire direction. Superdirective arrays are not applicable for a large number of elements as it is very difficult to maintain the magnitude and phase of the excitation accurately to each element. Most of the works published on the superdirective arrays are related to monopole wire antennas. A two element superdirective array of resonant monopoles is investigated [2]. A closely spaced folded monopole Yagi antenna with high gain is proposed [3]. A multiple arm folded element was used to impedance match a dipole closely spaced to a conducting ground plane [4]. This antenna gives maximum gain 8.5 dBi while the dipole is 0.25λ above ground plane. Apart from monopole wire superdirective arrays reported above, a 2-element low profile microstrip based folded monopole endfire array with maximum directivity 5.8 dBi at frequency 5.8 GHz is proposed [5]. A superdirective 5-element patch array is reported [6]. The planar monopole antennas provide more bandwidth than wire monopole antenna due to their larger surface area [7]. So, the designs of superdirective arrays for planar monopole antennas provide higher directivity in the wideband range [8-9].

The proposed SPICA has desirable characteristics, such as very wide bandwidth (1.05 GHz to 20 GHz), low cost, ease of manufacture, compact size, bidirectional radiation pattern; make this antenna very attractive to be employed in various applications. In this paper the application of SPICA as two element antenna array has been discussed. The directivity of the antenna is acceptable, but in many applications higher directivity is required. So, the directivity can be increased using an array made by two identical type antenna elements and separated by some distance. It will be shown that the phase of excitation and separation between elements greatly affects the directivity of antenna. When the antenna elements are very closely spaced and fed with equal amplitude but different phases, the resulting radiation pattern becomes more directional. The elements are fed by a feeding network with proper separation and phase of excitation to achieve better directivity.

II. DESIGN AND ANALYSIS OF TWO ELEMENT SPICA ARRAY

The geometry of the proposed SPICA with dimensions is shown Fig. 1. This antenna is designed using a 1.20 mm thick copper plate and fed by a SMA connector. The rounded metal ring acts as ground plane and a shorting strip is added to reduce the size of the antenna.

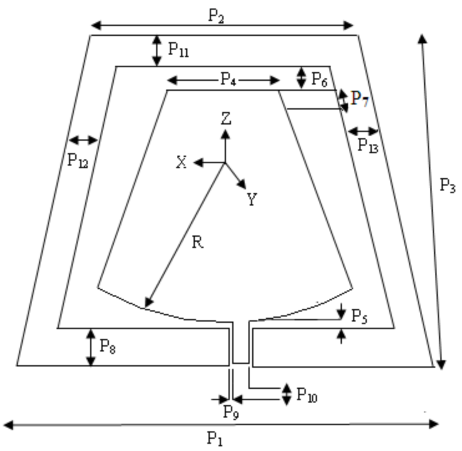

Fig. 1 Geometry of the SPICA: P_1 = 108 mm, P_2 = 68 mm, P_3 = 85.5 mm, P_4 = 26 mm, P_5 = 1.5 mm, P_6 = P_7 = 5 mm, P_{11} = P_{12}= P_{13}= 8 mm, P_9 = 1 mm, P_{10} = 4 mm, P_8 = 10 mm, R = 41 mm

The simulated return loss characteristic for PICA and SPICA is shown in Fig. 2. The rectangular box in the return loss plot of Fig. 2 indicates the lower operating frequency shifting to the lower side due to the shorting strip.

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The shorting strip yields 38% size reduction of the antenna. The photograph of fabricated SPICA is shown in Fig. 3.

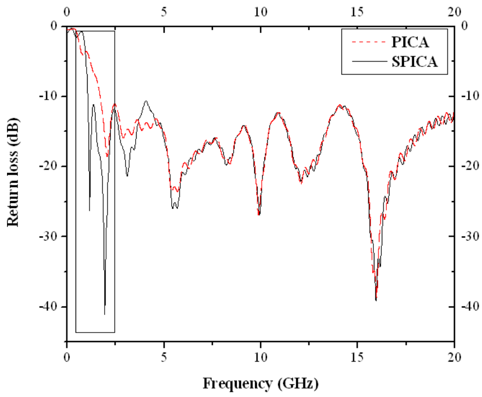

Fig. 2 Return loss characteristic for PICA and SPICA

Fig. 3 Photograph of fabricated SPICA

The simulated and measured return loss characteristic of the antenna upto frequency 8.5 GHz is shown in Fig. 4. Though this antenna has wider bandwidth, but the simulated and measured result of the return loss is shown upto 8.5 GHz due to the frequency limitation of the Agilent E5071B Vector Network Analyzer (VNA).

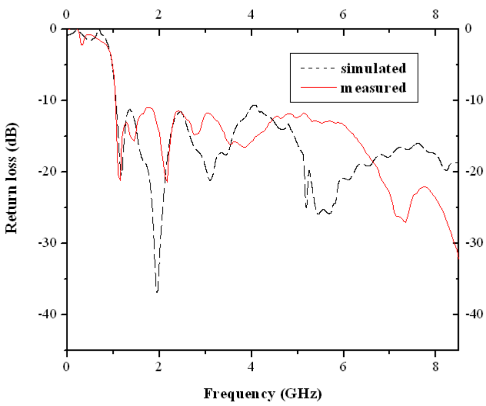

Fig. 4 Simulated and measured return loss of SPICA

Simulations are performed to analysis the characteristics of the array using CST MICROWAVE STUDIO 3D EM simulator, based on the method of finite integration technology (FIT). The antennas for array configuration are placed along Y axis as shown in Fig. 5. The spacing between the feed points of the antennas is denoted by S which should be correctly chosen to get desired performances.

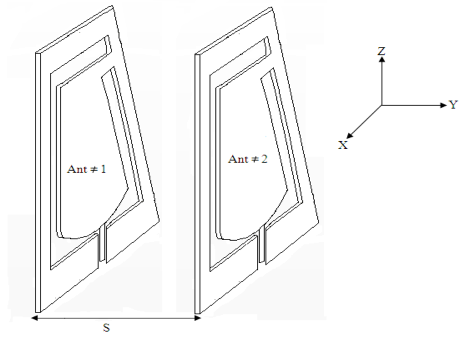

Fig. 5 Two element SPICA array along Y axis

The relative phase of excitation between the elements is adjusted when the amplitude of the excitation is kept at 1 volt and the distance between the elements is 20 mm. The phase of excitation for Ant#1 is set at 0^0 while phase of excitation for Ant#2 is varied between 90^0 to 270^0. The peak endfire directivity of the array versus relative phase of excitation at three different frequencies 3, 5.5 and 10.5 GHz is shown in Fig. 6.

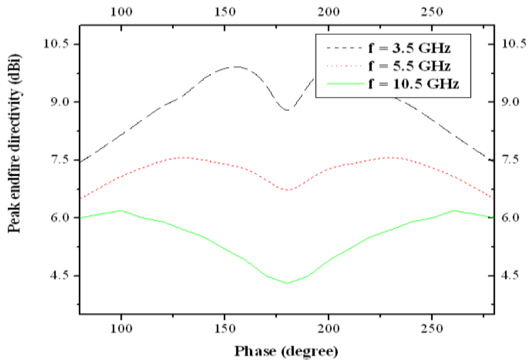

Fig. 6 Peak endfire directivity versus phase of excitation at different frequencies

It can be seen from Fig. 6 that 180^0 out of phase excitation gives less directivity. Fig. 6 shows if Ant#2 is fed at 150^0, the endfire directivity at different frequencies gives better results. The variation of peak endfire directivity for different spacing between the antennas with 150^0 phase of excitation at frequency 3 GHz is shown in Fig. 7. From Fig. 7 it is clear that 15 mm separation (S) between the antennas yields better directivity.

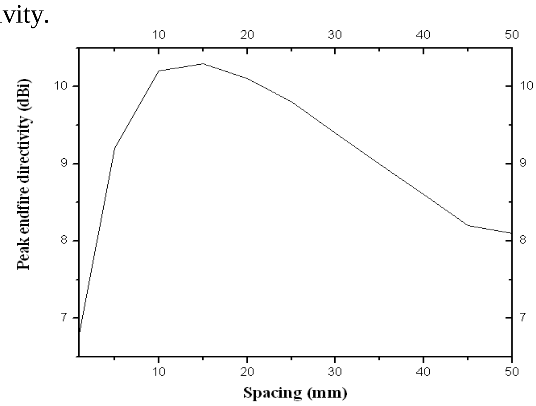

Fig. 7 Peak endfire directivity versus spacing between the antennas

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The peak endfire directivity for single and two element SPICA array in the operating frequency band is shown in Fig. 8. The directivity ranges from 3.502 dBi to 10.3 dBi for this array. It is observed from Fig. 8 that the peak endfire directivity for two element array is more than 3.5 dB better comparing with single element array in the operating frequency band. It is very difficult to obtain such higher directivity for equivalent conventional uniformly excited equally spaced two element array. So the proposed two element array of SPICA with peak endfire directivity above 10 dBi at some frequencies yields superdirective array characteristic.

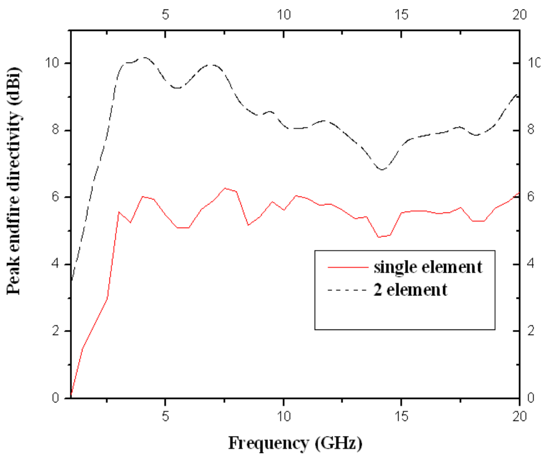

Fig. 8 Peak endfire directivity versus frequency for single and two element SPICA array

The plot of radiation efficiency of this array is shown in Fig. 9 which implies radiation efficiency above 98% in the operating frequency band.

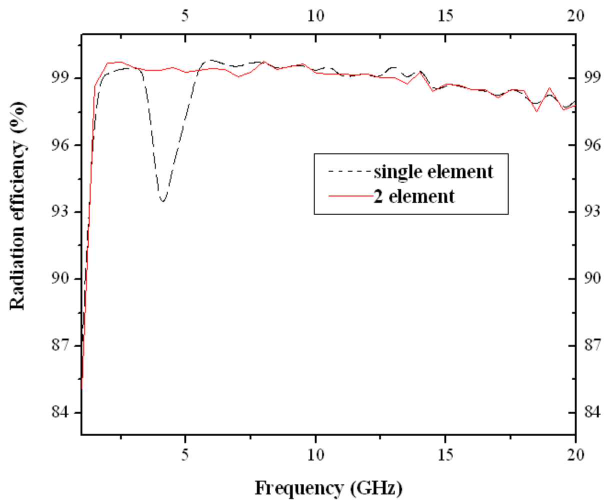

Fig. 9 Plot of radiation efficiency versus frequency for single and two element SPICA array

The farfield radiation pattern in the elevation and azimuth plane at frequency 5.5 GHz for single and two element array are shown in Fig. 10 and Fig. 11 respectively. The radiation pattern of the array is more directional comparing with single element array in the both elevation and azimuth plane.

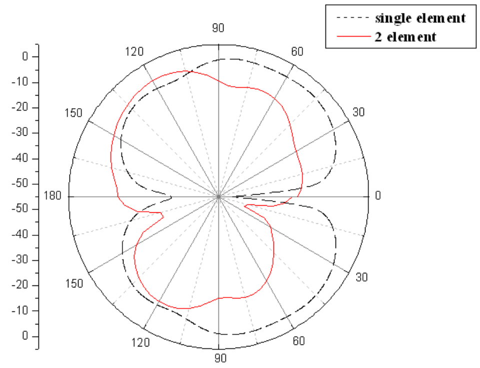

Fig. 10 Farfield radiation pattern at $\Phi = 90^0$ for single and two element array at frequency 5.5 GHz

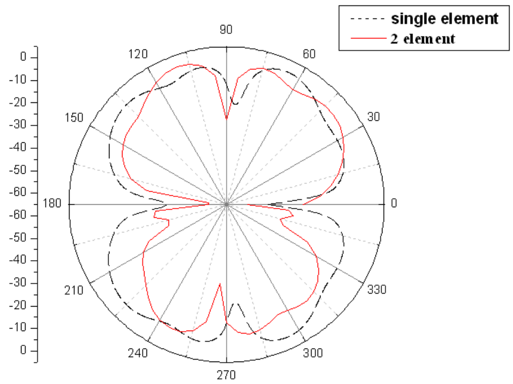

Fig. 11 Farfield radiation pattern at $\theta = 90^0$ for single and two element array at frequency 5.5 GHz

III. CONCLUSION

The study of the wideband SPICA as two element superdirective array has been discussed. The separation between the antenna elements and phase of excitation are varied to obtain better directivity. The peak endfire directivity of the array yields above 10 dBi at some frequencies. Due to the higher directivity and radiation efficiency, good gain characteristic can be obtained. The radiation pattern in elevation and azimuth plane of this array are more directional than those of single element array.

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